The Portable Remote Imaging Spectrometer (PRISM) Coastal Ocean Sensor

Pantazis Mouroulis, Byron E. Van Gorp, Robert O. Green, Michael Eastwood, Daniel W. Wilson, Brandon Richardson, Heidi Dierssen*

Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, 91109
**Department of Marine Sciences, University of Connecticut Avery Point, Groton, CT 06340*
Pantazis.Mouroulis@jpl.nasa.gov

Abstract: PRISM is an airborne pushbroom imaging spectrometer intended to address the needs of airborne coastal ocean science research. Its critical characteristics are high throughput and signal-to-noise ratio, high uniformity of response to reduce spectral artifacts, and low polarization sensitivity. We give a brief overview of the instrument and results from laboratory calibration measurements regarding the spatial, spectral, radiometric and polarization characteristics.

OCIS codes: (280.4788) Optical sensing and sensors; (300.6190) Spectrometers; (010.0280) Remote sensing and sensors

1. Introduction

There is a need in coastal ocean science for high spatial and temporal resolution spectral measurements to complement the capabilities of Earth-orbiting satellites. Airborne sensors such as PRISM provide on-demand monitoring of coastal areas to assess episodic events and also permit longer term monitoring at spatial scales that would be difficult to achieve from space. PRISM is scheduled for test flights in the spring and summer of 2012, after which time it is expected to be made available for use by the Ocean Science community.

Sensors for Ocean Science measurements are required to achieve a high signal-to-noise ratio in the visible and near infrared range while minimizing the polarization dependence of the sensor transmission. The PRISM design responds to these challenges by utilizing several innovations including: 1) a design that minimizes the number of elements, maintains low angles of incidence on optical surfaces, allows large aperture (F/1.8), and minimizes distortions, and 2) a polarization-insensitive diffraction grating fabricated by electron-beam lithography. The basic optical design concept was published in [1], and modifications to it along with theoretical predictions of stray light and polarization sensitivity were shown in [2]. A more detailed system description is found in [3].

PRISM comprises two instruments a pushbroom spectrometer with the characteristics of Table 1, and a spot radiometer (approximately 2 mrad field of view) operating at 1240 nm and 1610 nm to aid with atmospheric correction. In this summary we report on the spectrometer performance.

TABLE 1:SPECTROMETER SPECIFICATIONS

Spectral	Range	350-1050 nm
	Sampling	2.85 nm
Spatial	Field of view	30.8 deg
	Instantaneous FOV	0.95 mrad
	Spatial swath	610 pixels

2. System Description

The PRISM optical design ray trace is shown in Fig. 1. It incorporates a two-mirror wide field F/1.8 telescope and a spectrometer is of the Dyson form. A concave diffraction grating is used with a groove shape that departs from the triangular in order to provide a flatter efficiency through wavelength and also control the polarization variation. The Teledyne HyViSI® array with a 640x480 format and 27 μm pixel pitch is used. A two-band order-sorting filter is placed in close proximity to the array. The slit width is 27 μm.

A sensor head schematic is shown in Fig. 2. Bi-directional thermoelectric coolers are used to maintain spectrometer temperature at 25^{o} C and detector temperature at 5^{o} C during flight.

3. Measurements of system performance

Spectral sampling has been measured using Hg emission and laser lines of known wavelength. Full spectral response functions are measured through a scanning double monochromator throughout the entire spectral range and for five field positions. Fig. 3 shows example spectral response functions near the middle of the field.

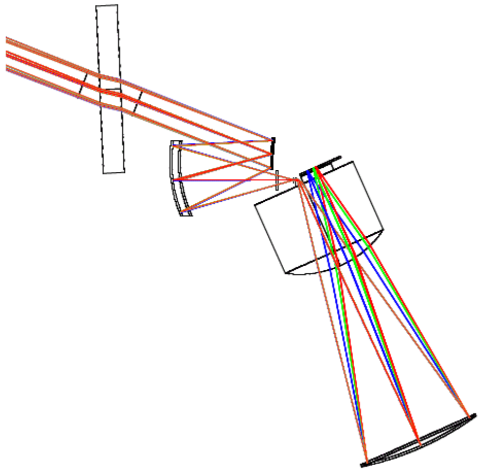

Fig. 1: Spectrometer and telescope raytrace in the direction of dispersion.

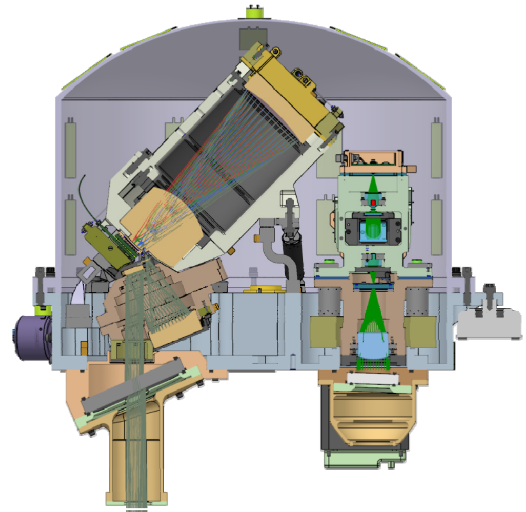

Fig. 2: Mechanical configuration of the sensor head showing spectrometer and IR spot radiometer (right) inside vacuum enclosure.

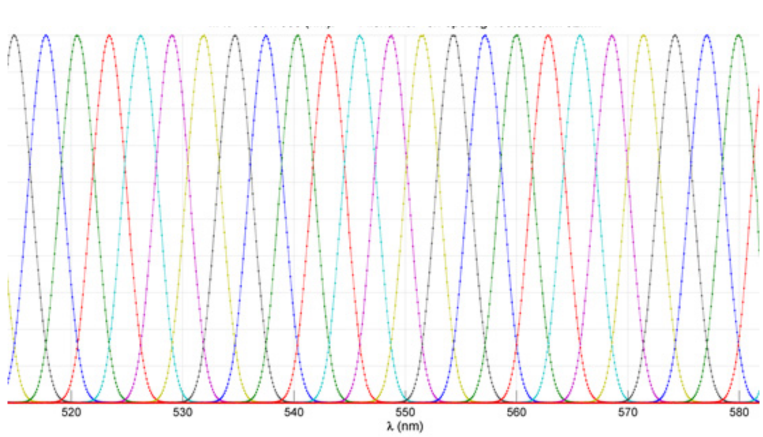

Fig. 3: Sample spectral response functions in the region 520-580 nm demonstrating 2.85 nm spectral sampling and 3.5 nm FWHM resolution,

The spatial response function is measured in the along-track and cross-track directions through scanning a sub-pixel slit illuminated with white light and oriented parallel or perpendicular to the slit. Fig. 4 shows results.

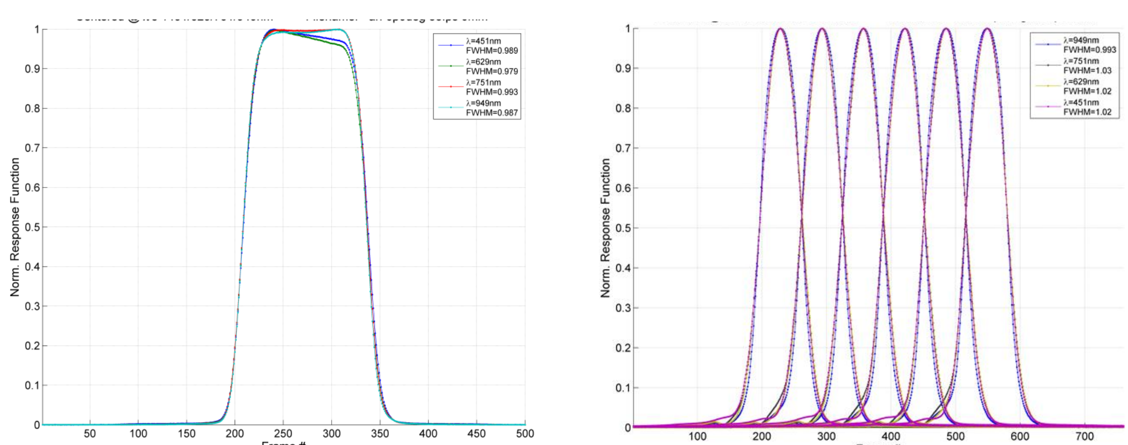

Fig. 4 Along-track (ARF, left) and cross-track (CRF, right) response functions for several wavelengths spanning PRISM spectral range. The ARF as shown does not include flight motion blur. In both cases, the FWHM resolution is just under 1.1 pixel. Very small to negligible chromatic variation is shown. The alignment of CRF peaks through wavelength is within 3% of a pixel.

Other measured characteristics of the spectrometer are shown in Figures 5-8. We believe that these characteristics set a new standard of performance for sensors of a similar type.

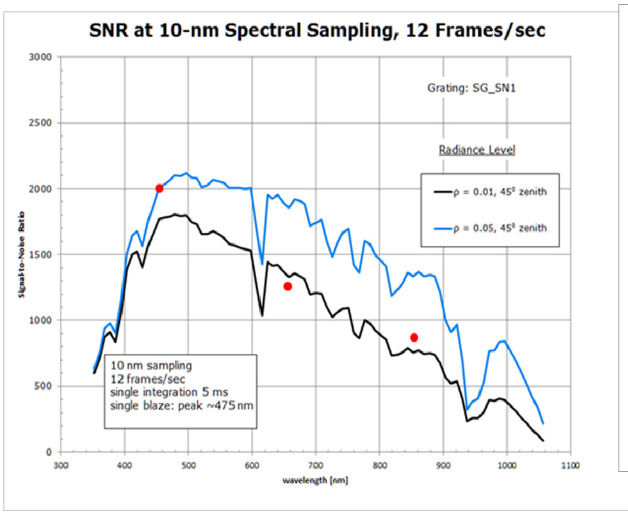

Fig. 5: Signal to noise ratio computed after inserting all measured values and using a spectralon panel illuminated with a NIST-traceable calibrated lamp. The SNR is referred to an equivalent 10nm spectral channel and 1/12 s integration time.

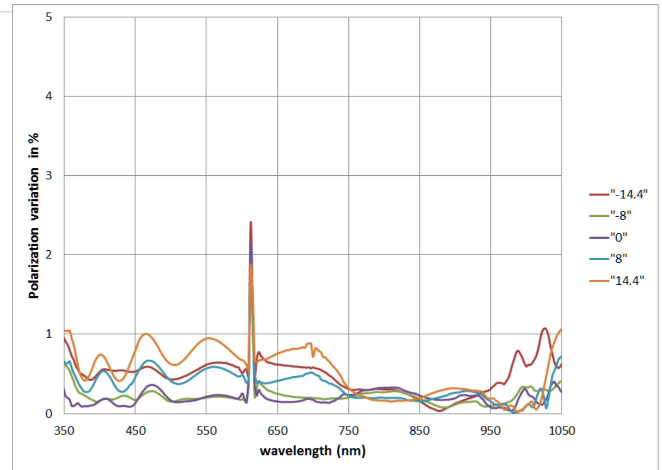

Fig. 6: Polarization sensitivity as a function of wavelength for five field points spanning the full field. .Variation is defined as $(I_{max}-I_{min})/(I_{max}+I_{min})$ * 100 as a polarizer with unpolarized light incident is rotated in front of the instrument. The spike is due to the order-sorting filter seam and affects two channels.

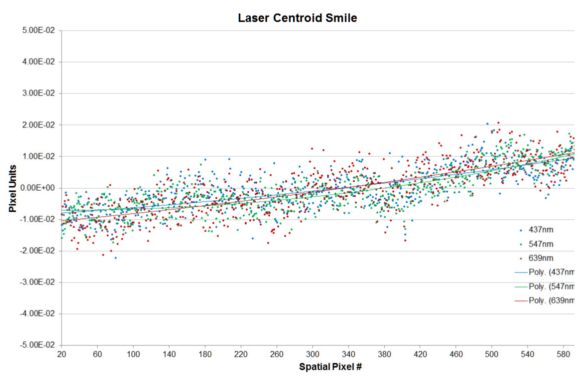

Fig. 7: Scatter diagram of spot centroids representing three different laser or Hg wavelengths show spectral uniformity to be within 3% of a pixel trough the entire field. A residual focal plane rotation of ~25 μrad has been left uncorrected.

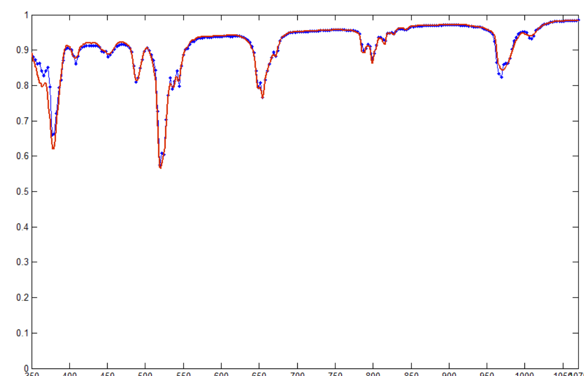

Fig. 8: Preliminary spectrum recovery from PRISM (blue line/points) compared with reference ASD spectrometer before full radiometric correction is applied shows excellent quality spectra. The object is Er-doped spectralon panel.

4. Acknowledgments

This research has been performed at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. The contributions of the JPL PRISM team and especially David Cohen, K. Balasubramanian, Scott Leland, Frank Loya, Doug Moore, David Randall, Jose Rodriguez, Chuck Sarture, Eugenio Urquiza, Victor White, and Karl Yee are gratefully acknowledged.

5. References

[1] P. Mouroulis, R. O. Green, and D. W. Wilson: "Optical design of a coastal ocean imaging spectrometer", Opt. Express **16**, 9087-9095 (2008) .

[2] B. Van Gorp, P. Mouroulis, D. Wilson, K. Balasubramanian, "Polarization and stray light considerations for the Portable Remote Imaging Spectrometer (PRISM)", Proc. SPIE 7812, 78120R-1 (2010).

[3] P. Mouroulis et al, "Design of an Airborne Portable Remote Imaging Spectrometer (PRISM) for the Coastal Ocean", http://esto.nasa.gov/conferences/estf2010/papers/vanGorp_Mouroulis_ESTF2010.pdf .